Fermi National Accelerator Laboratory

FERMILAB-Conf-99/205-E
CDF and D0

High P$_T$ Jet Physics

Freedy Nang
For the CDF and D0 Collaborations

University of Arizona
Tucson, Arizona 85721

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

July 1999

Proceedings of *XIII Rencontre de Physique de la Vallee d'Aoste*,
La Thuile, Italy, February 28-March 6, 1999

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

HIGH P_T JET PHYSICS

Freedy Nang
University of Arizona
Tucson, AZ 85721
on behalf of the CDF and DØ Collaborations

Abstract

Recent precise measurements of various jet cross sections have allowed stringent tests of next-to-leading order (NLO) predictions hinting the need for higher order calculations and/or the rethinking of the theoretical predictions. We examine the inclusive jet cross sections at center of mass energies of 1800 and 630 GeV and the ratio of these two cross sections. We also explore the sensitivity to parton distribution functions (PDF's) by looking at the triple differential dijet cross sections.

1 Introduction

Within the framework of Quantum Chromodynamics (QCD), inelastic scattering between a proton and an antiproton can be described as a hard collision between their constituents (partons). The outgoing partons are usually characterized as highly collimated streams of particles or "jets".

A breakthrough at the beginning of the decade enabled the calculation of the matrix elements at the next-to-leading order (NLO) or to the order of α_s^3. [1, 2, 3] New experimental data allows newer and more accurate fits of the parton distribution functions (PDF's). [4, 5]

2 Inclusive Jet Cross Section for $\sqrt{s} = 1800$ GeV

The CDF Collaboration has published a measurement of the inclusive jet cross section based on 19.5 pb^{-1} of $\bar{p}$p collisions at $\sqrt{s} = 1800$ GeV collected from 1992 through 1994 at the Fermilab Tevatron Collider. [6] More recently, the DØ Collaboration has published a similar measurement based on 92 pb^{-1} collected from 1994 through 1996. [7] The CDF experiment has also made a preliminary cross section measurement based on the 1994–1996 data set. Both experiments have also measured the cross section at $\sqrt{s} = 630$ GeV based on about 0.5 pb^{-1} of integrated luminosity. The ratio of the cross sections at the two center of mass energies allows for cancellation of several systematic uncertainties enabling a more precise test of the theoretical predictions.

The inclusive cross section, $< d^2\sigma/(dE_T d\eta) >$, is a counting experiment where one determines the number of jets in bins of transverse energy (E_T) within a fiducial region of interest. The CDF experiment has chosen this region to be $0.1 \leq |\eta| < 0.7$, where the pseudorapity, η is related to the polar angle θ by $\eta = \ln[\cot(\theta/2)]$. The DØ experiment has chosen two regions: $0.0 \leq |\eta| < 0.5$ and $0.1 \leq |\eta| < 0.7$. The former is the primary measurement and the latter allows for direct comparison with the CDF results.

Both experiments reconstruct jets using an iterative jet cone algorithm with a fixed cone radius of $\mathcal{R}$=0.7 in $\eta - \phi$ space where ϕ is the azimuthal angle. Data selection and corrections due to noise and/or contamination are described elsewhere. [6, 7]

The CDF Collaboration uses EKS [2] as their theoretical model for comparison while the DØ experiment uses JETRAD [3]. The theoretical models allow as input different choices of PDF's and the most recent ones were selected. [4, 5].

Figure 1 shows the ratios (D-T)/T for the CDF data (D) and EKS predictions for the theory (T) for different choices of PDF's in the $0.1 \leq |\eta| < 0.7$ region showing an excess for $E_T \geq 250$ GeV when compared to CTEQ4M. This preliminary measurement confirms the previous result showing an excess at high E_T. It has been speculated that an increase of gluons at high E_T would lead to more jets. The CTEQ collaboration has introduced the CTEQ4HJ PDF by forcing the fits to agree with the CDF data while keeping overall agreement with other experimental results, hence, explaining the good agreement between the CDF data and the theory with CTEQ4HJ for PDF.

Figure 2 shows a similar measurement from DØ in the $0.0 \leq |\eta| < 0.5$ region. Excellent agreement is observed for the entire E_T region. A numerical test based on $\chi^2 = \Sigma_{i,j}(D_i - T_i)(C^{-1})_{i,j}(D_j - T_j)$, where $C_{i,j}$ is the uncertainty covariance matrix, D_i and T_i represent the i-th data and theory points respectively, using the DØ data shows overall good agreement with different choices of PDF's. The overall systematic uncertainty is largely correlated. Table 1 lists the χ^2 values for JETRAD predictions with various PDF's. They describe both η regions: $0.0 \leq |\eta| < 0.5$ and $0.1 \leq |\eta| < 0.7$.

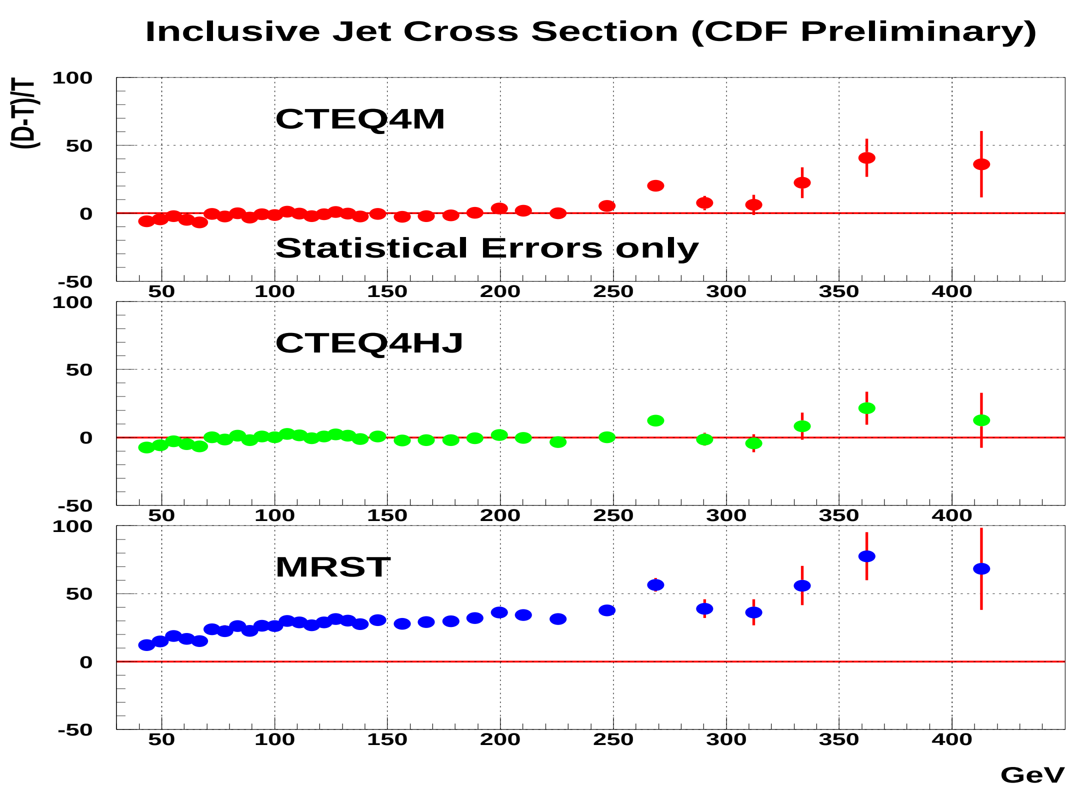

Figure 1: *Preliminary (D-T)/T from the CDF Collaboration for* $0.1 \leq |\eta| < 0.7$ *for different PDF choices.*

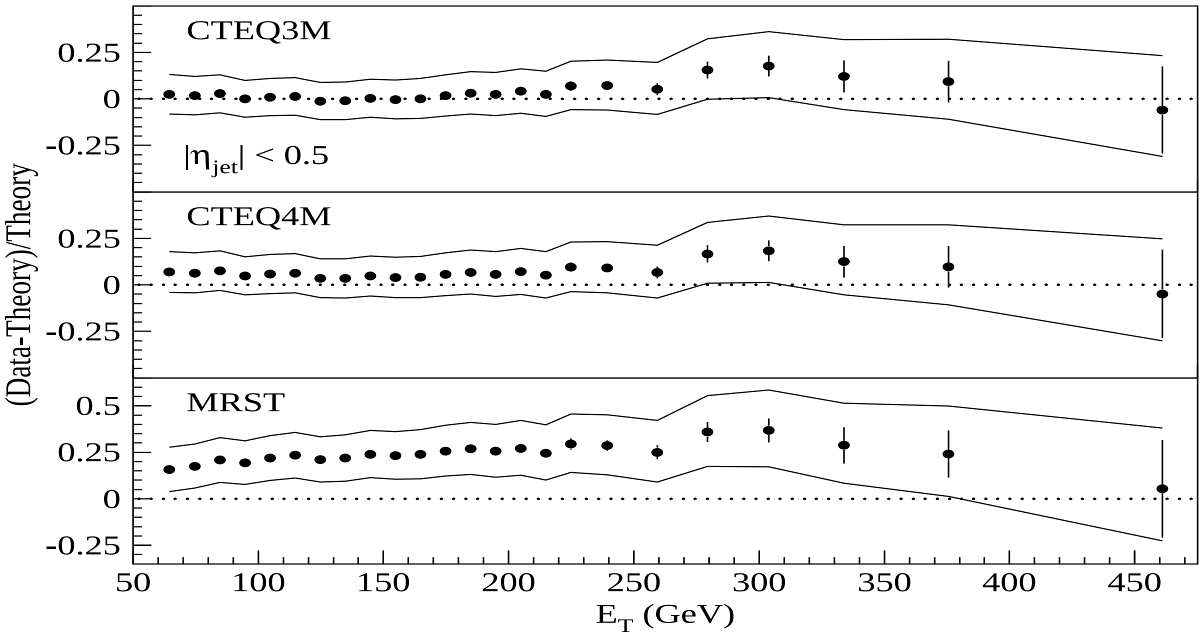

Figure 2: *Published (D-T)/T from the DØ Collaboration for* $0.0 \leq |\eta| < 0.5$ *for different PDF choices.*

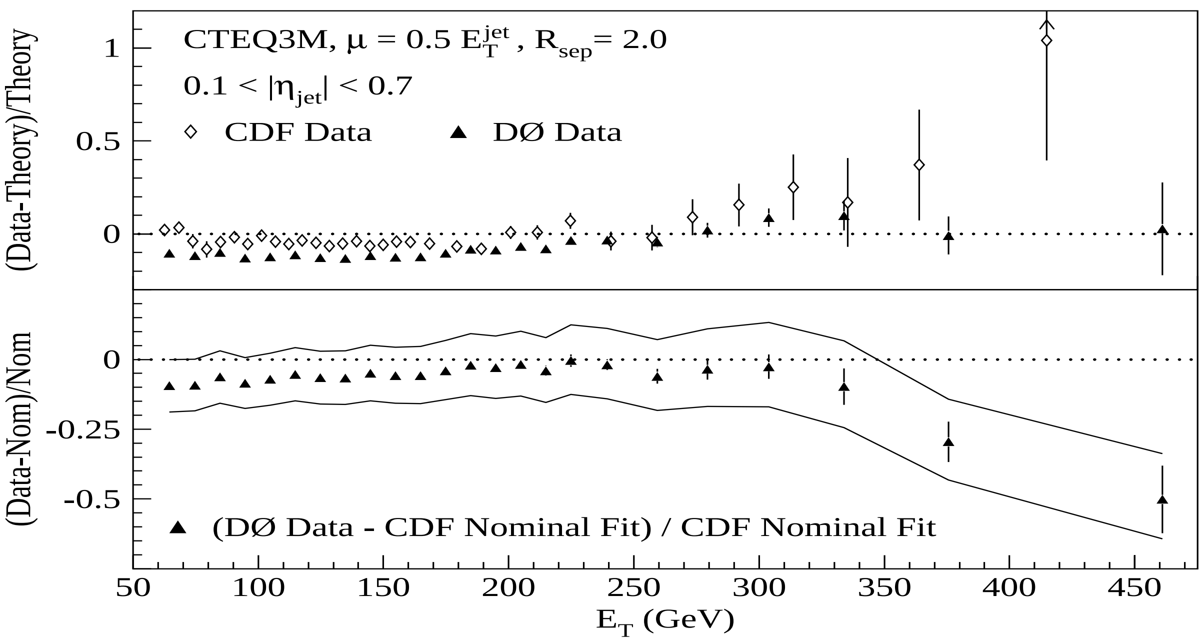

Figure 3: *Comparison of DØ published result to a fit of the CDF published result for the* $0.1 \leq |\eta| < 0.7$ *region.*

PDF	$0.0 \leq \|\eta\| < 0.5$	$0.1 \leq \|\eta\| < 0.7$
CTEQ3M	23.9	28.4
CTEQ4M	17.6	23.3
CTEQ4HJ	15.7	20.5
MRSA′	20.0	27.8
MRST	17.0	19.5

Table 1: χ^2 *comparisons between* JETRAD *and DØ data for* $0.0 \leq |\eta| < 0.5$ *and* $0.1 \leq |\eta| < 0.7$ *regions. There are 24 degrees of freedom.*

A direct comparison for both experimental published measurements was performed for the $0.1 \leq |\eta| < 0.7$ region and is shown in Fig. 3. Although the CDF data shows a rising trend for CDF not observed by DØ the two experiments are in good agreement and any discrepancy is well within the total systematic error band (not shown).

3 Inclusive Jet Cross Section for $\sqrt{s} = 630$ GeV

Both experiments have also measured the inclusive cross section at a lower center-of-mass energy, $\sqrt{s} = 630$ Gev. To allow for a direct comparison with the $\sqrt{s} = 1800$ Gev data, the data are plotted as a function of the variable x_T, defined as $x_T = 2E_T/\sqrt{s}$. Figure 4 shows the ratio of the scaled cross sections at $\sqrt{s} = 630$ GeV and $\sqrt{s} = 1800$ GeV for both experiments, compared to the same ratio in the theory, as a function of x_T. The shaded region shows the DØ systematic error bands. The CDF systematic errors are not available at this time. experimental results are in good agreement with each other but the theoretical predictions are 15% – 20% above the data.

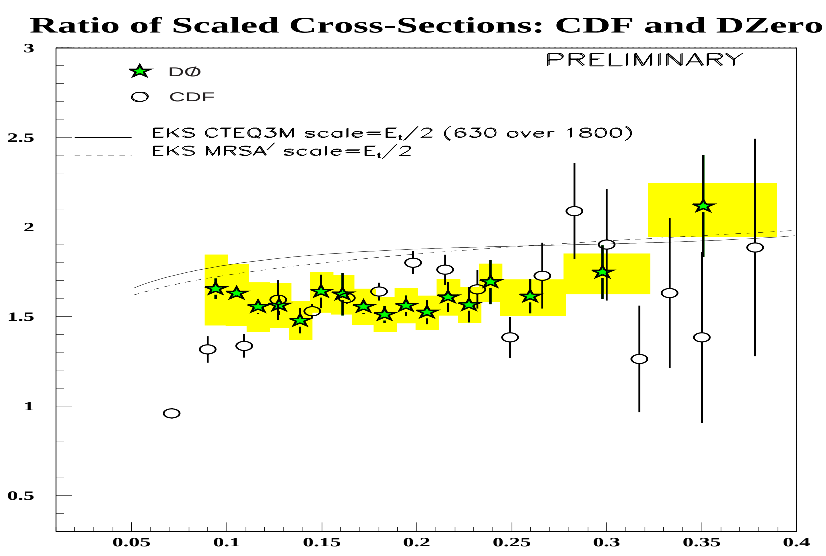

Figure 4: *Ratio of cross sections for the two center-of-mass energies.*

4 Triple Differential Dijet Cross Sections

As previously mentioned, a possible explanation for the excess of very high E_T jets observed by the CDF Collaboration is the choice of PDF used for the theoretical predictions. The CTEQ group has found that placing more gluons in the high x region does not strongly affect the fit with other experimental results and has made available the CTEQ4HJ PDF. [4)]

The triple differential dijet cross section, $< d^3\sigma/(dE_T d\eta_1 d\eta_2) >$, is ideal for the study of different PDF's because the choice of variables are sensitive to the PDF's, while being insensitive to the matrix elements. The CDF Collaboration requires the leading jet to be central ($0.1 \leq |\eta| < 0.7$) and plots the E_T of the leading jet for four different configurations defined by the location of the second leading jet: $0.1 \leq |\eta| < 0.7$, $0.7 \leq |\eta| < 1.4$, $1.4 \leq |\eta| < 2.1$, and $2.1 \leq |\eta| < 3.0$ as seen in Fig. 5. The (D-T)/T plots for various PDF's show better agreement with the CTEQ4HJ PDF as shown in Fig. 6.

The DØ Collaboration plots the E_T of the two leading jets when both jets are in one of the following η regions: $0.0 \leq |\eta| < 0.5$, $0.5 \leq |\eta| < 1.0$, $1.0 \leq |\eta| < 1.5$, and $1.5 \leq |\eta| < 2.0$. For each region, the data is further subdivided into two topologies: the opposite side (OS) configuration when both jets are in opposite η hemispheres; i.e., $\eta_1 * \eta_2 < 0$, and the same side (SS) configuration when both jets are on the same η hemisphere; i.e., $\eta_1 * \eta_2 > 0$. The purpose is to take full advantage of the relationship between x, E_T, and η:

$$x_1 = \frac{1}{\sqrt{s}}(E_{T1}\exp(\eta_1) + E_{T2}\exp(\eta_2)) \tag{1}$$

$$x_2 = \frac{1}{\sqrt{s}}(E_{T1}\exp(-\eta_1) + E_{T2}\exp(-\eta_2)) \tag{2}$$

Figures 7-10 show the (D-T)/T for the DØ data when compared to different PDF's and indicate overall agreement with both PDF's in all η regions.

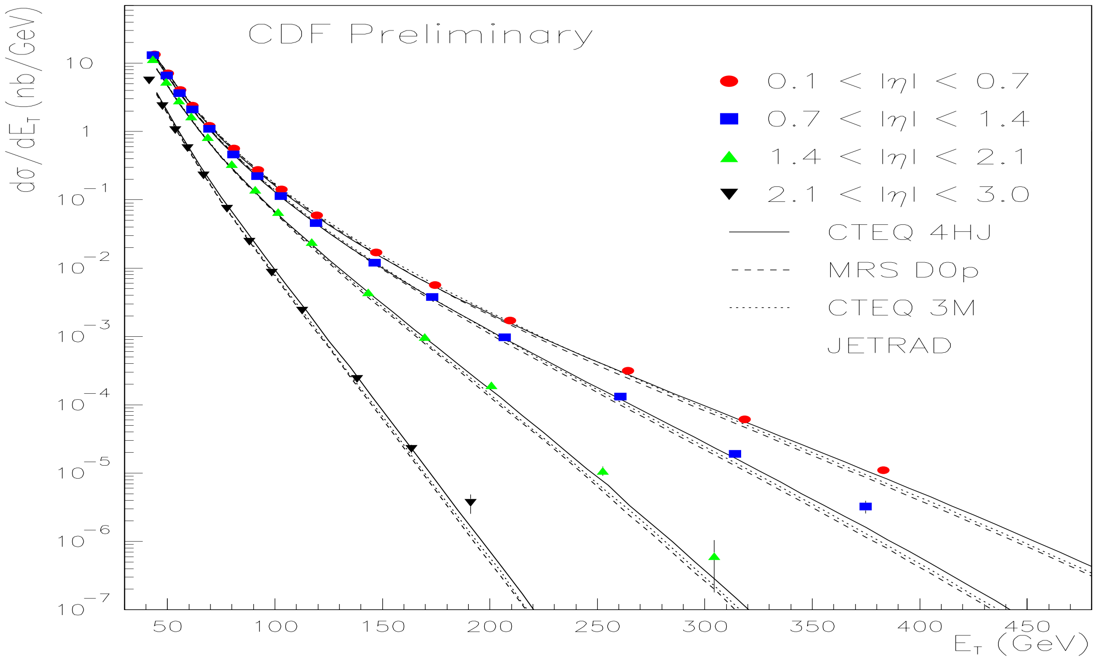

Figure 5: *CDF triple differential cross sections.*

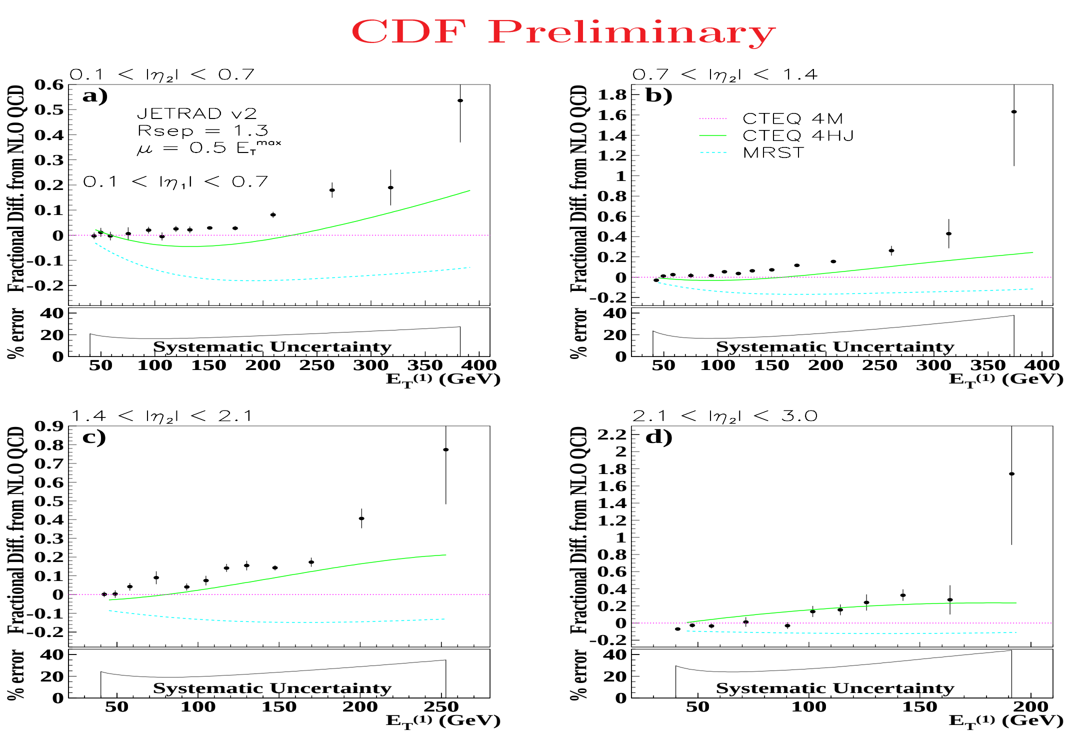

Figure 6: *(D-T)/T for the CDF triple differential cross section for different PDF's.*

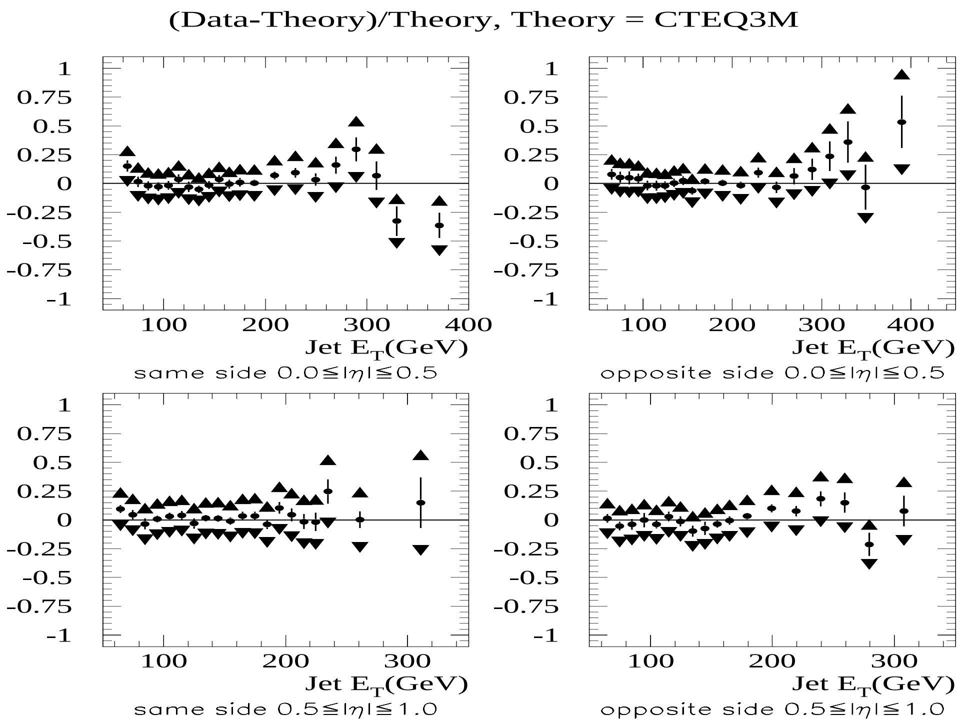

Figure 7: *(D-T)/T from the DØ Collaboration and* JETRAD *with CTEQ3M for* $0.0 \le |\eta| < 0.5$ *and* $0.5 \le |\eta| < 1.0$.

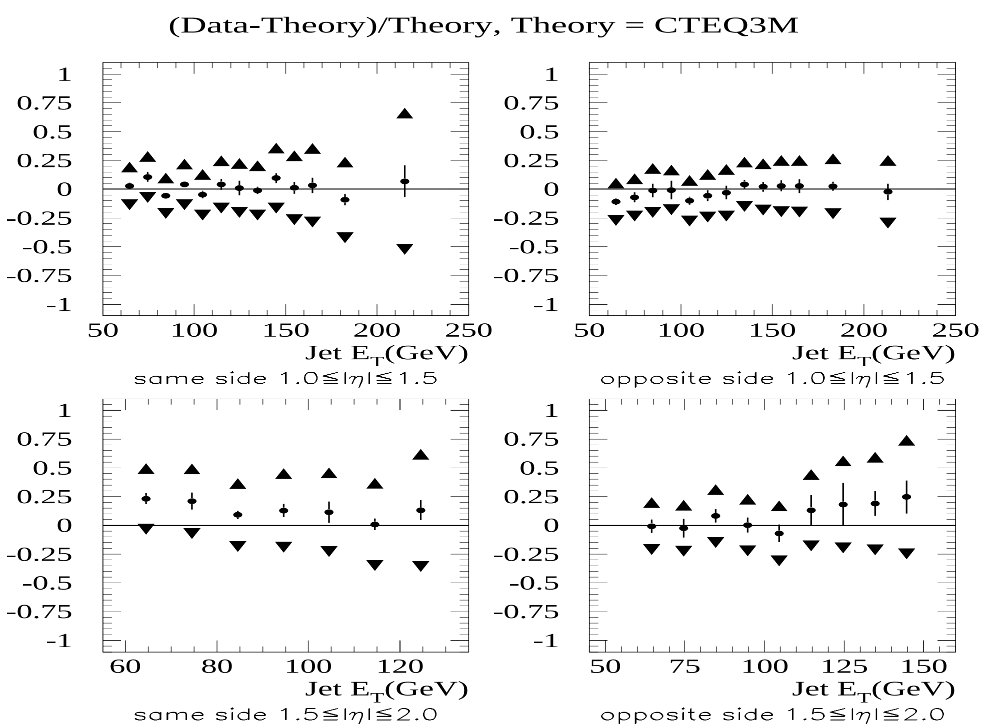

Figure 8: *(D-T)/T from the DØ Collaboration and* JETRAD *with CTEQ3M for* $1.0 \le |\eta| < 1.5$ *and* $1.5 \le |\eta| < 2.0$.

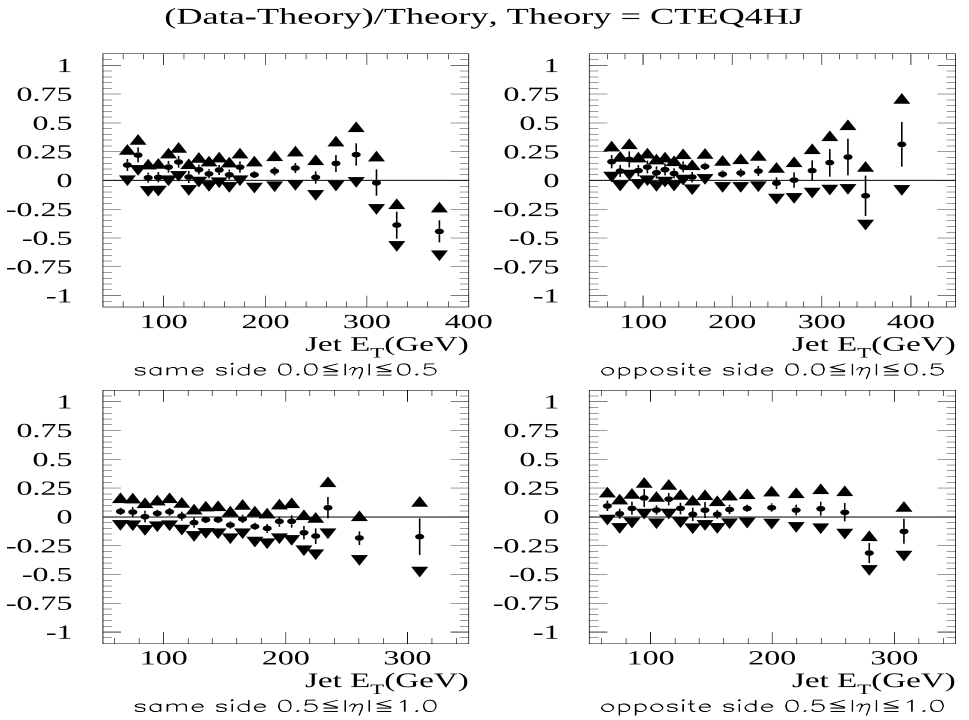

Figure 9: *(D-T)/T from the DØ Collaboration and* JETRAD *with CTEQ4HJ for* $0.0 \leq |\eta| < 0.5$ *and* $0.5 \leq |\eta| < 1.0$.

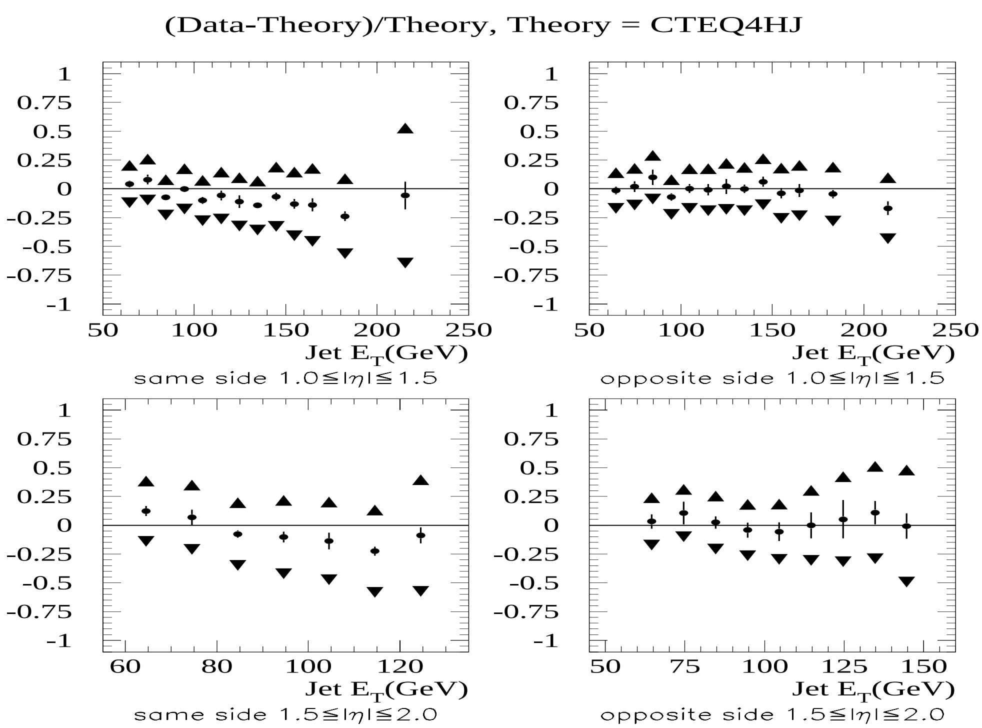

Figure 10: *(D-T)/T from the DØ Collaboration and* JETRAD *with CTEQ4HJ for* $1.0 \leq |\eta| < 1.5$ *and* $1.5 \leq |\eta| < 2.0$.

5 Conclusions

The CDF and DØ Collaborations have performed measurements using jets with uncertainties comparable to the theoretical ones. While the CDF inclusive measurement shows an excess at $E_T > 250$ GeV, the DØ measurement shows excellent agreement for the entire E_T region. Direct comparison of both measurements show that they are consistent given the magnitude and nature of the systematic uncertainties.

The $\sqrt{s} = 630$ GeV data and subsequent ratio to the $\sqrt{s} = 1800$ GeV are in agreement between the two experiments but lie below the theoretical predictions by 20%.

The CDF triple differential measurement also shows an excess at high E_T that can be accommodated with a PDF such as CTEQ4HJ. The comparable DØ measurement shows overall agreement for the entire E_T region.

References

1. F. Aversa *et al*, Nucl. Phys. **B327** (1989).

2. S. Ellis, Z. Kunszt, and D. Soper, Phys. Rev. Lett. **64**, 2121 (1990).

3. W. Giele, N. Glover, and D. Kosower, Phys. Rev. Lett. **B73**, 2019 (1994).

4. H. Lai *et al*, (CTEQ Collaboration), Phys. Rev. D **51**, 4763 (1995).

5. A.D. Martin *et al*, (MRST Collaboration), Eur. Phys. J. C **4**, 463-496 (1998).

6. F. Abe *et al*, (CDF Collaboration), Phys. Rev. Lett. **77**, 438 (1996).

7. B. Abbott *et al*, (DØ Collaboration), Phys. Rev. Lett. **82**, 2451 (1999).